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LA-UR-84-622

CONF-840255-4

LA-UR--84-622

DE84 007490

TITLE SPACE RESOLVED ABSOLUTELY CALIBRATED VUV SPECTROSCOPIC MEASUREMENTS ON CTX

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SUBMITTED TO 6th Symposium on Compact Toroid Physics Technology

Los Alamos

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FORM NO. 836 R4
ST. NO. 2629 5/81

Space Resolved Absolutely Calibrated VUV Spectroscopic Measurements on CTX

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Introduction

Absolutely calibrated VUV spectroscopic measurements have been taken on CTX. Three simultaneous measurements at different chordal positions (impact parameters of up to 31 cm) have been used to estimate spatial profiles, see Fig. 1.a. The intensity of the OV (629.7Å) and the OVI (1037.6Å) show a "pumpout" (from ~ 160 μs to 320 μs into the discharge) or impurity confinement that is spatially dependent with better confinement near the magnetic axis (τ_p ~ 90 μs). L_α(1215.7Å) measurements[1] also show similar behavior for the same portion of the discharge but has the added benefit of being useful for the duration of the discharge. Attempts to sustain the spheromak result in an increase of tungsten impurity radiation.

Three normal incidence 0.2 meter VUV monochromators were cross calibrated with an absolutely calibrated 0.4 meter VUV monochromator on loan from Johns Hopkins University.[2] They, and another 1 meter normal incidence VUV monochromator, have been used at 0° (0-cm impact parameter) to simultaneously monitor up to four separate spectral lines. The measurements were taken in the 80-cm-diameter copper-mesh flux conserver. The particle confinement time was analyzed only for decaying plasmas when the spheromak is fully disconnected from the source. The impurity studies portion of this paper was taken during several modes of sustained operation.

Particle Confinement Times

The particle confinement time was measured in two independent ways. In the slow mode of formation, the spheromak is completely disconnected from the source at about 160 μs and no further source of highly ionized oxygen is available. Most of the oxygen is in the OV and the OVI ionization states and the majority of the oxygen radiation comes from these states. From monitoring OV at 629.7Å and OVI at 1037.6Å plus the electron density from the interferometer one can calculate an oxygen confinement time. From the absolute intensities of the OV and OVI lines and assuming a density and a temperature one obtains the absolute density of OV and OVI (assuming coronal conditions). To obtain spatial spectral information, a subtraction is performed (Fig. 1.b.) by taking the average intensities of the outer chords and subtracting the average intensity multiplied by its effective path length from the next inner chord to find the inner chord average intensity, U.S.W.

Plots of the sum of OV and OVI densities for all three regions are shown in Fig. 2. Particle confinement times of τ_{22} ~ 90 μs, τ_{11} ~ 50 μs, and τ_{33} ~ 40 μs are obtained assuming a constant density profile and a temperature between 40 eV and 60 eV (as measured by Thomson scattering). Errors of up to 50% might be expected.

Space resolved L_a results give confinement similar to the oxygen pumpout. Following Ref. 1, we can calculate the ionization rates for a given intensity of L_α (Fig. 3) if we also know the temperature and the density. We know that

$$\frac{dn_e}{dt} = \frac{-n_e}{\tau_p} + \text{ionization rate},$$

where the ionization rate is found by from Ref. 1, and τ_p is the desired particle confinement time. During the time of oxygen pumpout we find from the L_α τ_p(region 3) ~ 55 μs, τ_p(region 2) ~ 110 μs, and τ_p(region 1) ~ 40 μs which are in good agreement with the oxygen pumpout rates. For later times during the density plateau ($n_e \sim 5 \times 10$ cm^-) the particle confinement times are τ_p(region 3) ~ 40 μs, τ_p(region 2) ~ 100 μs, and τ_p(region 1) ~ 30 μs, with errors of up to 50%. The data are summarized in table I.

Impurity Studies

For the slow mode of formation, the level of oxygen at 165 μs is approximately 4% at the magnetic axis, the line averaged level at this time is ~ 2.5%. We have again assumed a constant density and temperature profile.

Attempts at various forms of sustainment have been tried and have resulted in cold spheromaks with the exception of mixed mode operation. The mixed mode of formation involves formation in the slow mode plus an additional high inductance current source to add current at a low level to the spheromak. This was found to stabilize the n = 2 oscillations of the spheromak with little injection of additional impurities as shown in Fig. 4.b. Additional current above the mixed mode current (called here the overdriven mixed mode) resulted in substantial injection of impurities, a large fraction being heavy metals and the rest low level ionization states of low-Z impurities as shown in Fig. 4.e. In the long pulse sustained mode of operation, the source is run at low currents for a long period. Figure 4.f. shows that metals are injected into the spheromak to approximately the same proportions as in the overdriven mixed mode operation.

For the overdriven mixed and long pulse sustained modes of formation, the lines monitored and summed were not the complete set but only a substantial fraction, therefore only the trends of the radiation are to be noted and not the absolute values.

Summary

Space resolved particle confinement times have been measured in two independent methods in CTX. The confinement time near the magnetic axis was found to be $\tau_p \sim 100$ μs and a factor of two lower for the outer flux surfaces. Attempts at sustainment so far have resulted in cold plasmas and additional impurities being injected with the flux. This problem is being specifically addressed in the electrode facility.[5]

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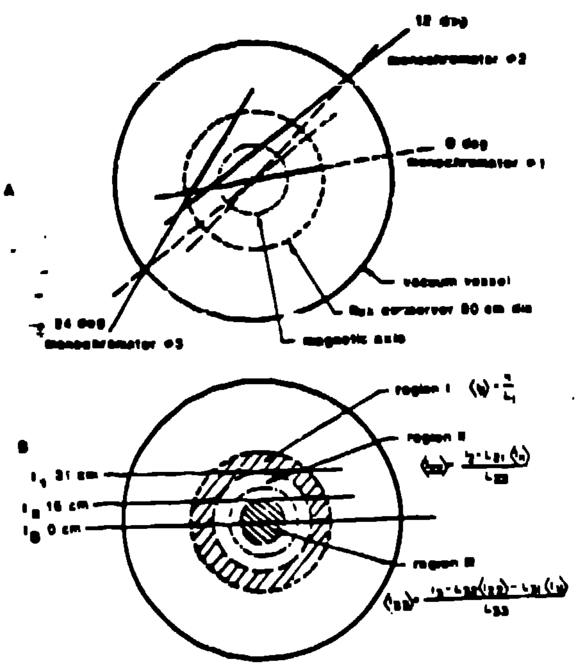
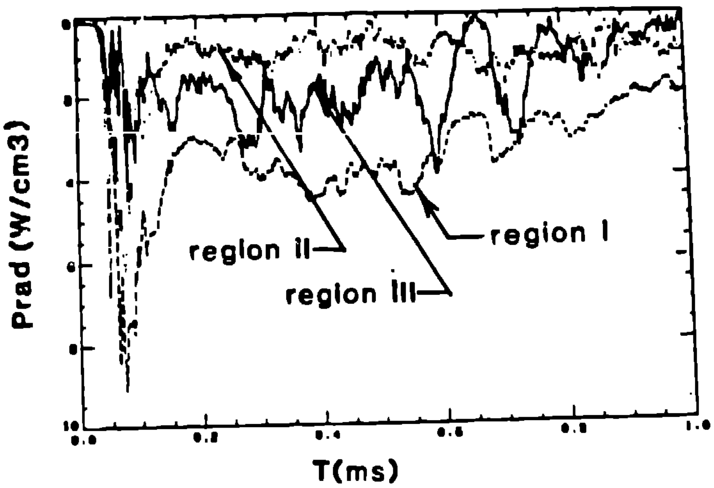


Fig. 1 a) Physical setup of VUV monochromators
b) Equivalent picture with subtraction routine.



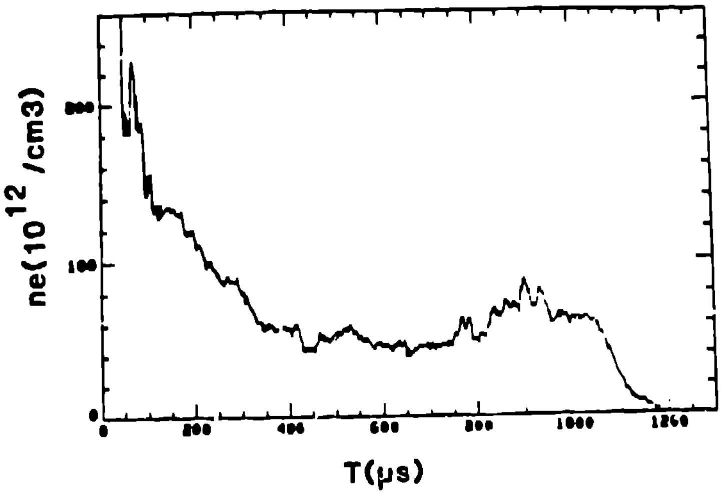


Fig. 3 a) L_α radiation powers for region 5 I, II, and III (b) Line-averaged electron density.

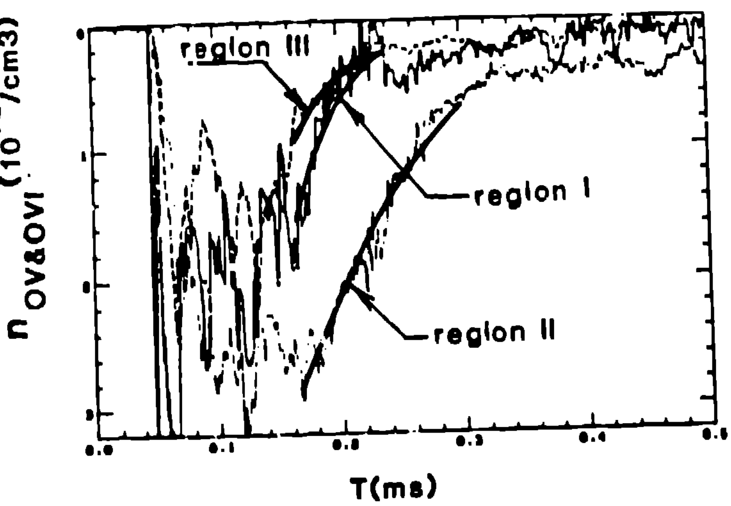
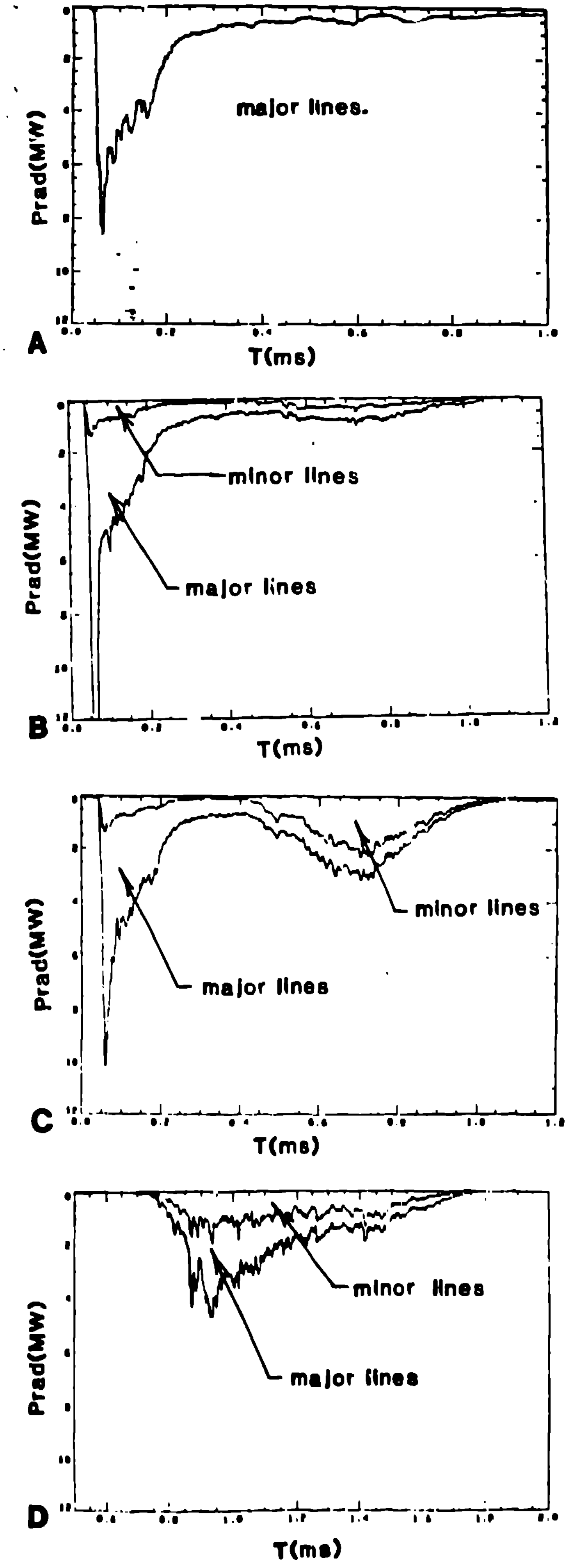


Fig. 2. Density of CV plus density of OVI for regions I, II, and III, $\tau_p(I) \sim 40\ \mu s$, $\tau_p(II) \sim 90\ \mu s$, $\tau_p(III) \sim 50\ \mu s$.

TABLE I

	pumpout OV & OVI	L_α	> 400 µs L_α only	
region 1	60 µs	40 µs	(20 eV) 50 µs	(10 ev) 35 µs
region 2	90 µs	110 µs	100 µs	
region 3	40 µs	66 µs	(20 eV) 40 µs	(10 eV) 60 µs

Summary of particle confinement time.



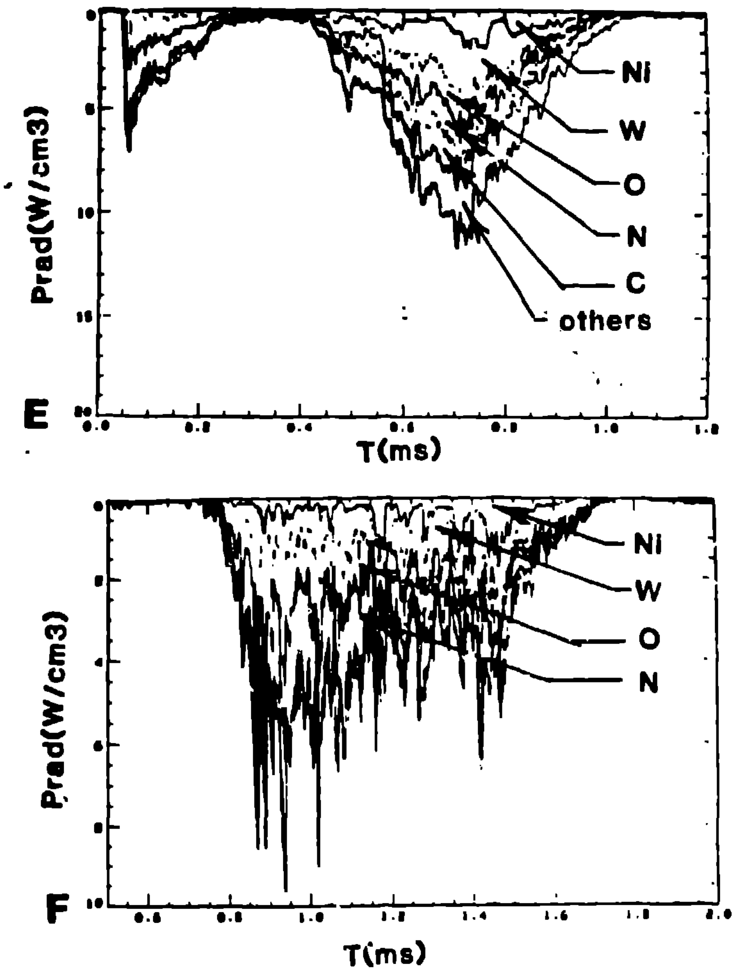


Fig. 4 a) Total power of the major impurity spectral lines (plus L_α) from 500 Å to 1250 Å for the slow mode formation.
b) Total power of the major and minor spectral lines for mixed mode formation. Major lines are those that dominate for the slow mode of formation and minor lines show up only as traces for the slow mode.
c) Major and minor impurity radiation for the long pulse sustained method of formation.
e) Composition of "minor" impurity radiation, metals plus low ionization states of O, N, C for overdriven mixed mode.
f) Composition of minor impurity radiation for long pulse sustained operation.